USAFSAM-TR-85-30

AD-A158 556

THE EFFECTS OF HYPOXIA INDUCED BY LOW ATMOSPHERIC PRESSURE ON SOFT CONTACT LENS WEAR

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June 1985

Final Report for Period June 1983 - January 1985

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NOTICES

This final report was submitted by personnel of the Ophthalmology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 2729-06-02.

The voluntary informed consent of the subjects used in this research was obtained in accordance with AFR 169-3.

This report has been reviewed and is approved for publication.

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:

3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S): USAFSAM-TR-85-30

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: USAF School of Aerospace Medicine

6b. OFFICE SYMBOL *(If applicable)*: USAFSAM/NGOP

7a. NAME OF MONITORING ORGANIZATION:

6c. ADDRESS *(City, State and ZIP Code)*: Aerospace Medical Division (AFSC) Brooks Air Force Base, Texas 78235-5301

7b. ADDRESS *(City, State and ZIP Code)*:

8a. NAME OF FUNDING/SPONSORING ORGANIZATION: USAF School of Aerospace Medicine

8b. OFFICE SYMBOL *(If applicable)*: USAFSAM/NGOP

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS *(City, State and ZIP Code)*: Aerospace Medical Division (AFSC) Brooks Air Force Base, Texas 78235-5301

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNI NO.
62202F	2729	06	02

11. TITLE *(Include Security Classification)*: THE EFFECTS OF HYPOXIA INDUCED BY LOW ATMOSPHERIC PRESSURE ON SOFT CONTACT LENS WEAR

12. PERSONAL AUTHOR(S): Flynn, William J.; Miller, Robert E., II; Block, Michael G.; Tredici, Thomas J.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Yr., Mo., Day)*	15. PAGE COUNT
Final Report	FROM 6/1/83 TO 1/1/85	1985 June	17

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB. GR.
06	16	
06	05	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*: Aviation; Contact Lens; Cornea; Corneal Edema; Hypoxia; Low Atmospheric Pressure

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Contact lens use in aviation has long been a subject of debate and controversy. One of the major concerns for contact lens wear at altitude is the potential for corneal edema and subsequent visual degradation, due to the reduced levels of oxygen available for normal corneal metabolism. Four subjects were tested, wearing both high- and low-water content soft contact lenses, for visual changes and adverse corneal physiological responses due to hypoxia induced by an atmospheric pressure level equivalent to 10,000 ft. Results of this study indicate that, although the cornea is placed under higher levels of physiologica stress at an altitude of 10,000 ft, the absence of visual degradation or significant symptoms suggests that lenses can be safely worn under the conditions of this study.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER *(Include Area Code)*	22c. OFFICE SYMBOL
WILLIAM J. FLYNN, Captain, USAF, BSC	(512) 536-2745	USAFSAM/NGOP

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS P

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THE EFFECTS OF HYPOXIA INDUCED BY LOW ATMOSPHERIC PRESSURE ON SOFT CONTACT LENS WEAR

INTRODUCTION

Contact lens use in aviation has long been a subject of debate and controversy. Numerous anecdotal reports and letters have appeared in the literature describing wearer's discomfort when using contact lenses during aircraft flights (1-4). Major concerns voiced in the past for contact lens wear at altitude were the potential for corneal edema, because of the reduction in oxygen available for normal corneal metabolism and the possibility of subcontact lens bubble formation due to low atmospheric pressure.

Since the cornea is an avascular tissue, its primary open-eye source of oxygen is from the ambient air. At sea level, the oxygen partial pressure of this source is approximately 155 mm Hg and decreases exponentially with increasing altitude. For instance, at an air altitude of 10,000 ft, the oxygen partial pressure is reduced to 109 mm Hg. A contact lens placed between this source and the cornea must possess sufficient oxygen transmissibility to meet an 11- to 19-mm Hg O_2 critical level in order to prevent hypoxia and permit a normal state of corneal hydration (5).

Subcontact lens bubble formation from low atmospheric pressure was reported by Jaeckle as early as 1944 (6). Even after many advances in contact lens fitting and design characteristics, Newsom et al. (1969) reported bubble formation in 66% of 16 polymethyl methacrylate (PMMA) wearers tested (7). With the advent of soft hydrophilic lenses, the new property of gas permeability was introduced to contact lens practitioners. As a result of this gas permeability, subcontact lens bubbles have not been reported at tested altitudes as high as 37,000 ft (8-10).

Traditionally, the United States Air Force (USAF) has prohibited the wearing of contact lenses by all aircrew members (21). This policy was predicated on the real and significant limitations of early contact lens technology. Now, with the advent of new lens materials, the appropriateness of this policy has fallen under close scrutiny. Currently, 50% of the navigators and 20% of the pilots in the USAF require spectacle lens correction to meet flying standards (11). Serious compatibility problems with existing aircrew spectacles have been created by new generation chemical/biological life-support gear, night vision goggles, eye protective devices, and helmet-mounted target sights. For this spectacle compatibility problem, contact lenses would appear to be a viable alternative--certainly one that is worthy of investigation. However, concerns remain about the potential adverse effects of contact lens wear at altitude. Therefore, this study was designed to investigate the effects of hypoxia, under low atmospheric pressure (equivalent to an altitude of 10,000 ft), on soft contact lens wear.

METHODS

Four subjects, from whom informed consent had been obtained, participated in the study. All were free of ocular disease and had ocular parameters within normal limits (Table 1). All subjects were initially unadapted lens wearers, and were required to achieve 20/20 or better acuity with the contact lenses. Each subject was fitted with two types of soft (HEMA) lenses, a low-water (45%) and a high-water (71%) contact lens. Both lens types had approximately the same average oxygen transmissibility (12). Two subjects were initially fitted wtih low-water-content lenses, and the other two were fitted with high-water-content lenses. All subjects wore their lenses on a daily basis for 2 to 5 months before testing began. After having completed testing of the first lens type, the subjects were switched to the second lens design; and an additional month of adaptation was allowed.

Both types of contact lenses were evaluated, along with spectacle wear as a control, during 4-hr chamber flights at two altitudes: 10,000 ft and ground level. Desired atmospheric pressure levels were achieved in the USAF School of Aerospace Medicine altitude chambers at an average temperature of $26.9 \pm 1.7^{\circ}C$ and a relative humidity of $49.8 \pm 5.3\%$.

During the chamber flights, visual acuities (both distance and near) were recorded every half hour by use of a Bausch & Lomb Visual Testing Apparatus - Near and Distance (VTA-ND). A complete slit-lamp examination, including the instillation of sodium fluorescein, and corneal curvature measurements were obtained just before and immediately after the chamber flights. Every hour, during the chamber flights, a slit-lamp examination was performed to evaluate: lens fit, tear quality, conjunctival injection, and corneal integrity. In this evaluation, lens fit was judged to be steep, flat, or good; and the amount of lens movement was estimated. Tear quality (debris, completeness) and conjunctival injection were graded on a scale from 0 to 4 (Table 2). The quality of keratometry mire reflections was graded over the contact lenses every hour on the scale in Table 2. Also, every half hour, the subjects were required to grade any symptoms relating to eye or lens awareness and clarity of vision, on the same grading scale.

RESULTS

Visual acuity for all subjects under all test conditions remained at 20/20 or better throughout the chamber flight. Fluctuations of plus or minus 1 line (e.g., 20/15 to 20/17) did occur with both contact lenses and glasses, but more frequently with contact lenses (Table 3).

EDITOR'S NOTE: For the convenience of the reader, all of the tables have been grouped at the close of this Report.

Both conjunctival injection and tear debris increased during the 4-hr chamber flights (Figs. 1 and 2). This increase occurred for both contact lenses and spectacles, with consistently higher levels for the contact lenses. No significant difference was found between the high- or low-water contact lenses for either the amount of conjunctival injection or tear debris.

Postchamber flight corneal curvatures varied little from the preflight measurements (less than 0.37 diopters). One subject (both eyes) did develop corneal striae with both lens types during the chamber flights at 10,000 ft, and not during the ground-level testing. Results of postflight fluorescein examinations are shown in Table 4. No alterations were detected in lens fit or in keratometry measurements over contact lenses.

Subjective responses to vision clarity varied little from baseline during the chamber flight, and no significant difference existed between contact lenses and glasses. One subject did report a slight degradation in his visual clarity during the chamber flights at 10,000 ft, but this effect occurred for both contact lens types and spectacles. The subjective responses to eye or lens awareness did increase for contact lens wear during the chamber flight at 10,000 ft (Fig. 3), whereas the same graded responses to spectacles showed little change.

DISCUSSION

For many years the prime concern of contact lens wear during aircraft flight was bubble formation due to low atmospheric pressures. For rigid, non-gas permeable lenses, this effect was reported to occur at altitudes greater than 18,000 ft (6, 7). Reports of low atmospheric pressure effects on soft hydrophilic contact lenses indicate the absence of bubble formation at tested altitudes up to 37,000 ft (8-10). Accordingly, bubble formation with soft contact lens wear at altitude should not be a concern.

Thus, uncertainties for soft contact lens wear at aircraft cabin pressure levels should be limited primarily to the effects of hypoxia and dry air (13-16). In this study, at an atmospheric pressure equivalent to 10,000 ft and at relatively high humidity levels, we evaluated the effects of hypoxia from low atmospheric pressure on soft contact lens wear.

Both military and civilian passenger and cargo aircraft are normally pressurized to a cabin altitude of 5,000-8,000 ft. In this study, with an atmospheric pressure level slightly higher than that of cargo and passenger planes, no significant changes in contact lens vision due to the hypoxia were detected. Although contact lens vision did fluctuate up and down by one line (Tables 3 and 4), no significant difference was noted between the fluctuations at ground level or at 10,000 ft. This finding seems to indicate that small fluctuations in visual acuity are inherent to HEMA lenses, as has been suggested elsewhere (17, 18).

Some ocular effects of hypoxia induced by low atmospheric pressure may be reflected in Figures 1 and 2 and in Table 3. Conjunctival injection and tear debris increased for both contact lenses and spectacles during the 4-hr chamber flights at 10,000 ft, with consistently higher levels being noted for contact lenses. Possibly more specific to the effects of hypoxia with low atmospheric

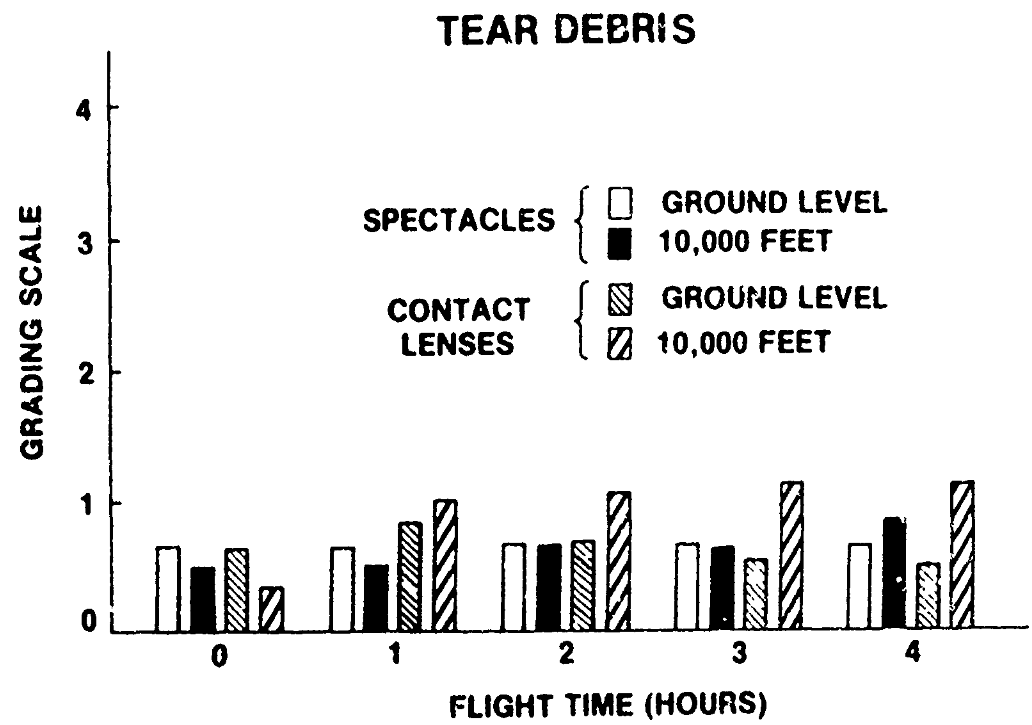

Figure 1. Mean changes in tear film debris during the 4-hr chamber flights. (Contact lenses: N = 16; spectacles: N = 8)

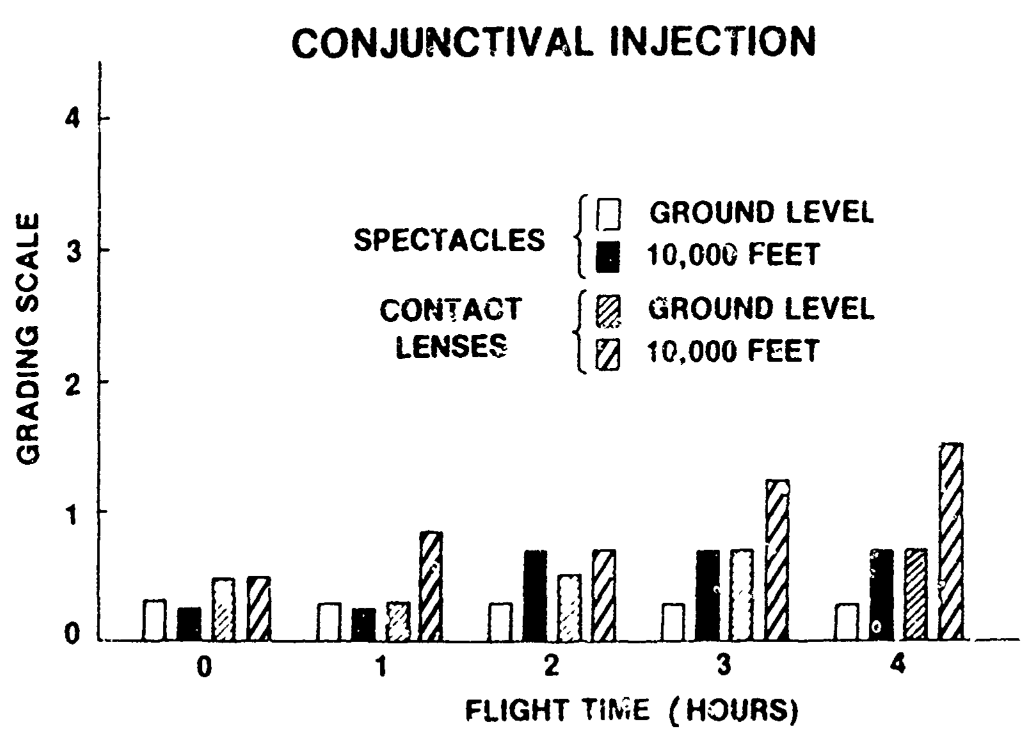

Figure 2. Mean changes in conjunctival injection during the 4-hr chamber flights. (Contact lenses: N = 16; spectacles: N = 8)

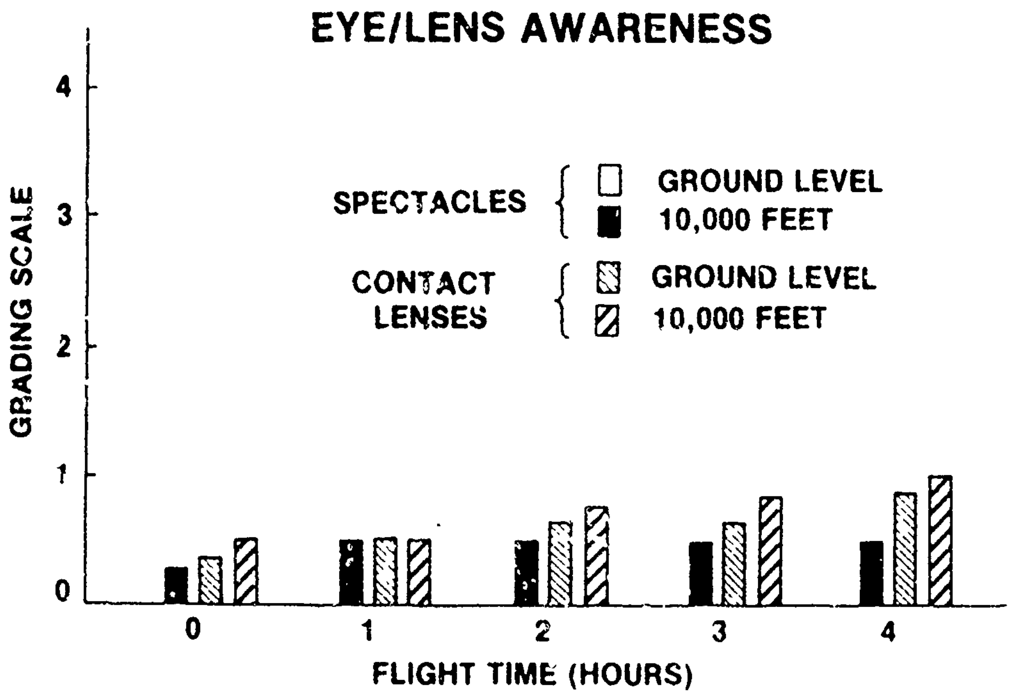

Figure 3. Mean changes in eye or lens awareness reported by the test subjects during the 4-hr chamber flights. (Contact lenses: N = 16; spectacles: N = 8)

Note: Grading scale reading for spectacles at ground level equals zero.

pressure are the greater number of eyes with positive postflight fluorescein staining, and the detection of corneal striae at 10,000 ft (19, 20), as shown in Table 3.

The results of this study indicate that the physiological response of the cornea to soft contact lenses is subject to significantly higher levels of stresses at an altitude of 10,000 ft than at ground level. Under these higher stress levels, however, the visual performance with soft lenses remained unchanged from ground-level wear. This lack of visual performance degradation, as well as the absence of significant symptoms with the soft lenses at 10,000 ft, suggests that soft lenses can be safely worn under the conditions outlined in this Report.

Of importance, however, is the fact that the commonly reported complications of soft contact lens wear may occur at a higher rate than normal, especially with prolonged or repeated exposure to the environmental conditions in this study. Therefore, individuals regularly wearing soft lenses aboard airplanes should be required to adhere to frequent followup examinations and proper lens-care hygiene. The effects of additional environmental factors in the aircraft cabin, such as dry air and cigarette smoke, will be the subject of future reports from this laboratory.

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TABLES 1 - 4

TABLE 1. SUMMARY OF SELECTED OCULAR PARAMETERS

Subject	Age	Sex	Refraction	Corneal Curvature
KJ	19	M	-0.75 -0.25 X 110	40.87/40.62 @ 084
			-0.75 -0.25 X 050	40.50/40.87 @ 090
LH	25	F	-4.50 DS	44.00/44.50 @ 090
			-3.75 -0.25 X 120	43.50/43.75 @ 090
GJ	27	M	-2.75 -0.75 X 135	43.00/44.00 @ 050
			-1.00 -0.75 X 060	43.25/44.00 @ 130
LM	37	M	-2.75 -0.75 X 130	43.75/43.00 @ 130
			-3.25 -0.75 X 051	42.75/44.00 @ 115

TABLE 2. EXAMINER AND SUBJECT GRADING SCALE FOR SLIT-LAMP FINDINGS, KERATOMETRY REFLECTION QUALITY, AND SUBJECT SYMPTOMS

0 = NONE AND/OR NORMAL

1 = MINIMAL

2 = MODERATE

3 = SEVERE

4 = EXTREME, REMOVE LENSES

TABLE 3: Parts A and B. NUMBERS AND RANGE OF VISUAL ACUITY LINE FLUCTUATIONS FOR EACH SUBJECT, WEARING SPECTACLES OR CONTACT LENSES, DURING THE 4-HR CHAMBER FLIGHTS. (Visual acuity is in minimum angle resolvable.)

PART A: Right Eye

RIGHT EYE	GROUND LEVEL					
	TYPE OF OPTICAL CORRECTION					
SUBJECT	NUMBER OF VISUAL ACUITY LINE CHANGES			VISUAL ACUITY RANGE (HIGH/LOW)		
	71% H_2O LENS	SPECTACLES	45% H_2O LENS	71% H_2O LENS	SPECTACLES	45% H_2O LENS
LM	1	0	0	.85/1.0	.60	1.0
KJ	2	0	4	.75/.85	.75	.75/1.0
GJ	2	0	5	.60/.75	.75	.75/1.0
LH	3	0	3	.85/1.0	1.0	.75/.85

RIGHT EYE	ALTITUDE = 10,000 FEET					
	TYPE OF OPTICAL CORRECTION					
SUBJECT	NUMBER OF VISUAL ACUITY LINE CHANGES			VISUAL ACUITY RANGE (HIGH/LOW)		
	71% H_2O LENS	SPECTACLES	45% H_2O LENS	71% H_2O LENS	SPECTACLES	45% H_2O LENS
LM	1	0	0	.75/.85	.60	1.0
KJ	3	0	3	.75/.85	75	.85/1.0
GJ	0	0	5	.75	.75	.75/.85
LH	0	1	0	.75	.75/1.0	1.0

(Cont'd on facing page)

TABLE 3 *(Cont'd)*

PART B: Left Eye

LEFT EYE	GROUND LEVEL					
	TYPE OF OPTICAL CORRECTION					
SUBJECT	NUMBER OF VISUAL ACUITY LINE CHANGES			VISUAL ACUITY RANGE (HIGH / LOW)		
	71% H_2O LENS	SPEC-TACLES	45% H20 LENS	71% H_2O LENS	SPEC-TACLES	45% H_2O LENS
LM	0	0	0	.75	.60	1.0
KJ	3	0	1	.60/1.0	.75	.60/.75
GJ	2	0	2	.60/.75	.75	.85/1.0
LH	3	0	4	.75/1.0	1.0	.75/.85

LEFT EYE	ALTITUDE = 10,000 FEET					
	TYPE OF OPTICAL CORRECTION					
SUBJECT	NUMBER OF VISUAL ACUITY LINE CHANGES			VISUAL ACUITY RANGE (HIGH/LOW)		
	71% H_2O LENS	SPEC-TACLES	45% H_2O LENS	71% H_2O LENS	SPEC-TACLES	45% H_2O LENS
LM	1	0	0	.60/.75	.60	1.0
KJ	2	2	4	.60/.75	.60/.75	.85/1.0
GJ	2	0	2	.75/.85	.75	.85/1.0
LH	1	0	7	.85/1.0	1.0	.75/1.0

TABLE 4. RESULTS OF POSTFLIGHT FLUORESCEIN STAINING AND CORNEAL STRIAE DETECTION DURING THE 4-HR CHAMBER FLIGHTS

Lens H_2O Content	Altitude Level	Number Of Eyes with Staining (%)	Number Of Eyes with Straie (%)
45%	10,000	3 (38%)	2 (25%)
	Ground Level	2 (25%)	0
71%	10,000	2 (25%)	2 (25%)
	Ground Level	1 (13%)	0
Total	10,000	5 (31%)	4 (25%)
	Ground Level	3 (19%)	0